3.1 The Great Cooling

Figure C3.2: The Cypress Hills area includes sediments from the Cenozoic Era.

Cypress Hills Interprovincial Park rises above the surrounding prairies. It spans the southern border of Alberta and Saskatchewan. The park has been described as an island of forest within a sea of grassland. Due to its higher elevation, Cypress Hills receives much more precipitation than the surrounding areas. As a result of the extra moisture, this rich forest ecosystem attracts many tourists every year.

Cypress Hills provides clues about Alberta's geological past. The 600-m thick section of sedimentary rock that lifts this area above the surrounding grasslands was not removed by the advancing ice sheet during the most recent Ice Age. At that time, geologists suspect this area was an island of land in a sea of ice called a *Nunatak* (Inuktitut for "land apart"). This rare record of **Cenozoic Era** sediments provides scientists with an amazingly complete record of the last 65 million years of Alberta's history.

Cenozoic Era: the last 65 million years of Earth's history

The Cenozoic Era

Millions of Years Ago	Era	Period	Epoch
1.7	CENOZOIC	Quaternary	Holocene
			Pleistocene
		Tertiary	
65	MESOZOIC	Cretaceous	
140		Jurassic	
210			

Rising Mountains

The Cenozoic Era (65 million years ago to the present) is the last of the eras in Earth's history. It is divided into two periods—the Tertiary Period (from 65 million years ago to 1.7 million years ago) and the Quaternary Period (from 1.7 million years ago to the present). The Tertiary Period was much longer than the Quaternary Period, making up over 97% of the Cenozoic Era. Recall from Chapter 2 that at the beginning of the Cenozoic Era, the collision between the North American Plate and the Pacific Plate was at its most intense—this resulted in a rapid period of mountain building that finally ended about 50 million years ago. The result was the enormous Rocky Mountain Range. However, at the time these mountains were not so rocky. They were round-looking mountains covered with V-shaped valleys cut out by erosion.

Cenozoic Era: 65 million years ago to the present
Tertiary Period: 65 million years ago to 1.7 million years ago
Quaternary Period: 1.7 million years ago to the present

The relentless march of the tectonic plates not only resulted in mountain building—it also caused Alberta and the rest of North America to slowly migrate northward. As North America moved north, its climate got cooler. Eventually, it would end up in its present location with a climate cold enough to form glaciers. These glaciers would carve out the familiar jagged features of the Rocky Mountains. This icy process began approximately 1.7 million years ago.

A Retreating Sea

Near the beginning of the Cenozoic Era, the Bearspaw Sea retreated to the southwest—this left most of Alberta high and dry. During this time the Bearspaw Sea had dumped sediment on most of southern Alberta, which left the Bearspaw sedimentary rock formation. This formation is rich with dinosaur fossils and other fossils.

During the Cenozoic Era, a new source of sedimentary rock was the run off from the rising Rocky Mountain Range. Large rivers flowed down V-shaped valleys and dumped sediment into the foothills region of Alberta.

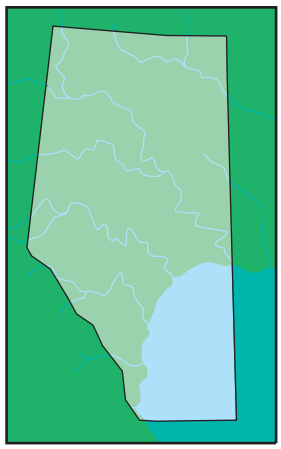


Figure C3.3: During the late Cretaceous Period, much of southern Alberta was submerged under the Bearspaw Sea.

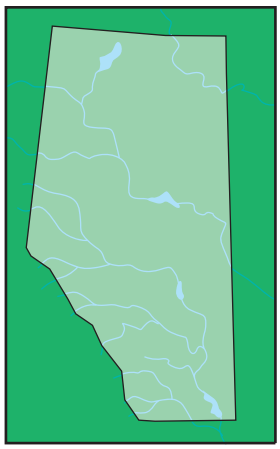


Figure C3.4: By the beginning of the Cenozoic Era, the Bearspaw Sea had retreated to the southeast.

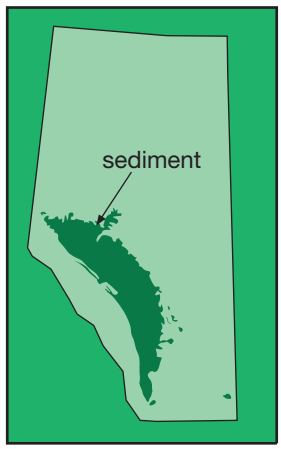
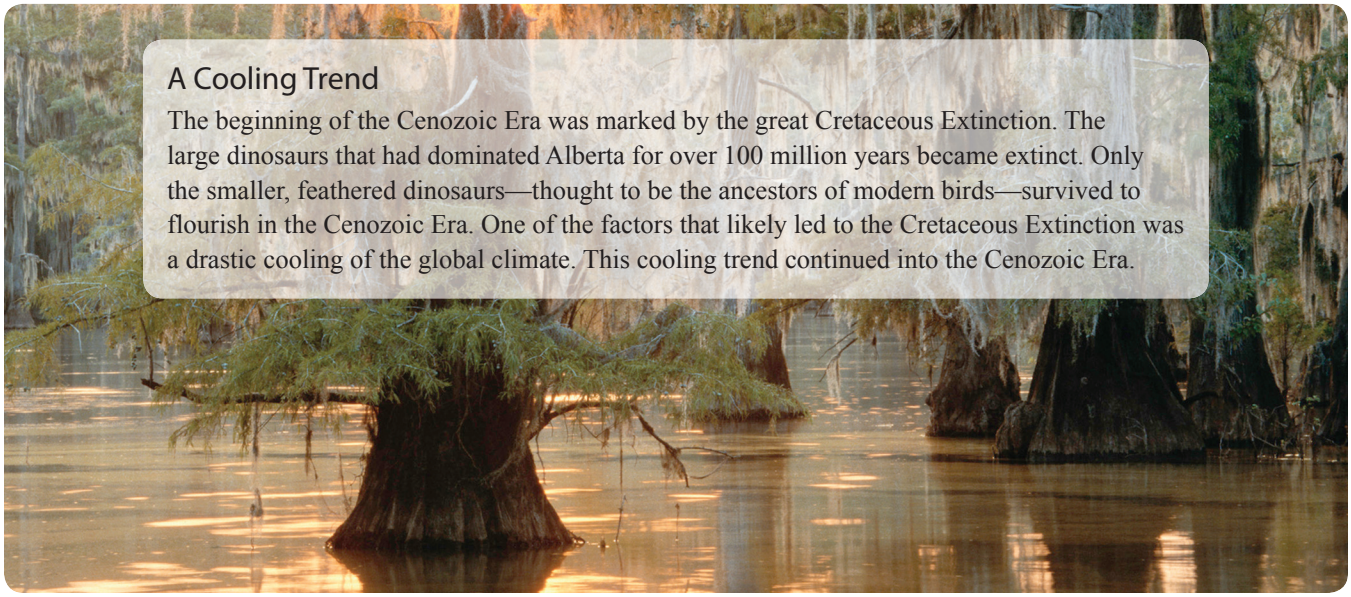


Figure C3.5: Cenozoic sedimentary rock outcrops are evidence of rivers pouring sediment from the Rocky Mountains.

Practice

1. Many geologists suspect that the draining of the Bearspaw Sea was a consequence of the final set of collisions between the North American Plate and a plate supporting arcs of volcanic islands. Explain how these final collisions could have caused the Bearspaw Sea to drain.
2. In Chapter 1 you learned that the Lethbridge area is rich in ammonite fossils. Explain the source of these fossils and the sedimentary rock that encases these fossil beds.



A Cooling Trend

The beginning of the Cenozoic Era was marked by the great Cretaceous Extinction. The large dinosaurs that had dominated Alberta for over 100 million years became extinct. Only the smaller, feathered dinosaurs—thought to be the ancestors of modern birds—survived to flourish in the Cenozoic Era. One of the factors that likely led to the Cretaceous Extinction was a drastic cooling of the global climate. This cooling trend continued into the Cenozoic Era.

Figure C3.6: This swamp resembles early Cenozoic Alberta.

During the first 15 million years of the Tertiary Period, scientists believe there was a significant drop in average global temperatures. The cooling not only affected Alberta's animal life; it also caused a drastic change in plant life. The tropical rain forests gave way to more temperate evergreen forests scattered with rivers, lakes, and swamps. It was cooler than the Cretaceous Period, but still warmer than it is today. About two-thirds of the way through the Tertiary Period, Alberta is thought to have resembled present-day southern Louisiana.

Figure C3.7: Evergreen forests began to dominate the Tertiary Period in Alberta.

The Cypress Hills Fossils

The Cypress Hills Formation (35 to 42 million years old) in southeastern Alberta contains many fossils from the Tertiary Period. It shows an amazing array of mammals. The Cypress Hills fossils include mice, flying lemurs, bats, rabbits, dog-sized horses, giant pig-like mammals, and even rhinoceroses. Around 40 million years ago, geologists suspect that temperatures must still have been much warmer than they are today. Fossil evidence indicates that crocodiles terrorized these wetlands. Late Tertiary fossils (about 14 million years old) from the Handhills Formation in south-central Alberta and Wood Mountain in Saskatchewan show the presence of herds of horses, camels, and elephant-like mastodons.

The Rise of the Mammals

At the time of the Cretaceous Extinction, the surviving mammals were mainly small rodents. These furry creatures moved in on the territory of the extinct big dinosaurs. By 40 million years ago, many new forms of mammals appear in the fossil record—these were the ancestors of modern hooved herbivores, flesh-eating carnivores, and large-brained primates.

Figure C3.8: A 195-million-year-old fossil skull could be one of the earliest ancestors of modern primates. Believe it or not, this tiny fossil is noted for its relatively large brain!

65 million to 40 million years ago: mammals diversify and flourish

Grasses, Grazers, and Big Predators

Figure C3.9: The dense root structure of grasses allowed them to withstand the cooler and drier climate of the late Tertiary Period.

The spread of large herds of grazing species in the late Tertiary Period is believed to be closely linked to the dominance of grasses around the same time. Grasses are found in just about every type of environment around the world—there are about 9000 species of grasses worldwide. The first grass species appear in the fossil record early in the Tertiary Period but don't begin to dominate until late in the period when Alberta had become significantly cooler. As the climate became cooler and drier, the deep and dense roots of grasses helped them survive. The fossil record shows the gradual transition of the wetlands of the early Tertiary Period into drier woodlands and then eventually into grasslands.

One theory suggests that the new dominance of grasses was partly due to a new ability of hooved mammals to digest cellulose (the main component of plant cell walls). Mammals that can digest cellulose are called ruminants. New herds of grazing ruminants gave grasses a distinct survival advantage over other plants because they grow from the base, while other plants grow from the tip. The resistance of grasses to grazing is an adaptation that transformed the landscape of Alberta in the late Tertiary Period. It became grassland, which was home to giant herds of grazers and the predators that stalked them. More cooling was still to come.

Figure C3.10: Alberta farmers harvest grasses, such as wheat.

Practice

3. Explain why mowing a lawn does not kill the grass, but a cat can kill some house plants by chewing off too many leaves.
4. The description of the Tertiary grasslands relates giant herds of large grazing mammals stalked by predators. Identify an area on Earth's current landscape that could be described in a similar way.

Evidence for a Cooling Trend

Scientists believe there was an overall cooling trend during the Tertiary Period. This was just one of many climate changes in Earth's past. What evidence do scientists have of past climate changes? The evidence can be found in sedimentary rocks. For example, the presence of tropical plant and animal fossils in current-day polar regions indicate these places must have been much warmer in the past.

Conversely, the absence of tree pollen from current tropical landscapes indicates that the past climate was too cold for trees to survive. Similarly, the evidence found within sedimentary rock layers gives scientists many clues about the Tertiary cooling trend.

Figure C3.11: Current examples of pollen and pollination are shown in these three photos. Meanwhile, a lack of tree pollen from current tropical landscapes shows the past climate was too cold for trees to survive.

Investigation

A Record in Deep-Ocean Sediments

Purpose

You will explore a key line of evidence that has helped scientists develop theories about climate change.

Part A: Oxygen Isotopes in Shells

Problem

What is the relationship between the ratio of oxygen isotopes (oxygen-18: oxygen-16) and deep ocean temperature?

Background

Foraminifera is a group of organisms that lives in oceans around the world. These tiny, single-celled animals have calcium carbonate ($CaCO_3(s)$) shells and are found in a wide variety of marine environments.

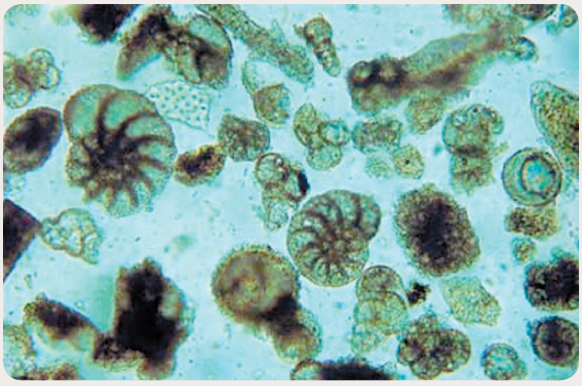


Figure C3.12: Foraminifera live in oceans.

The oxygen present in the calcium carbonate of the shells comes from the oxygen in water ($H_2O(l)$). When Foraminifera die, they settle to the ocean's bottom and become part of the sediment. Foraminifera are frequently used by scientists to deduce information about ancient environments because these organisms have many favourable characteristics for these studies:

- Their hard shells tend to be well preserved.
- They are very abundant—up to a million individuals live in a square metre. This means that small samples of sediment can provide ample data.
- Since these organisms are single-celled, they respond quickly to environmental changes. Their shell chemistry can act as an indirect record of environmental changes.
- Some species of Foraminifera can only survive in water at specific temperatures. This provides additional environmental information.

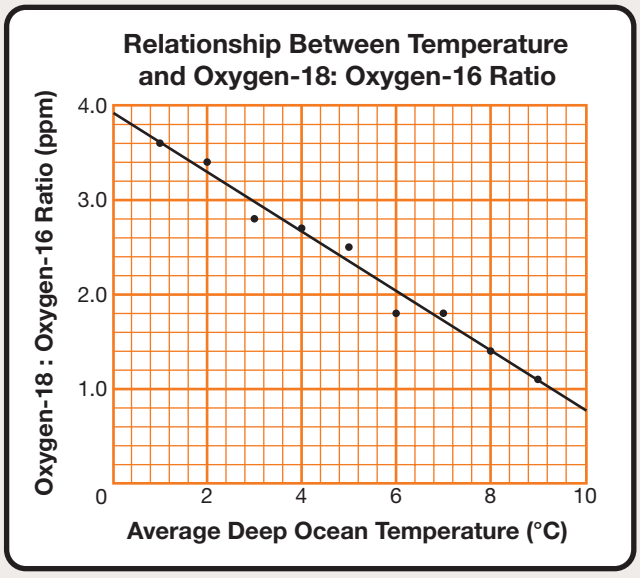
Science Skills

✓ Analyzing and Interpreting

Scientists can measure the amount of each oxygen isotope in the calcium carbonate layers. The ratio of the two stable isotopes—oxygen-18 (very rare) to oxygen-16 (very common)—has been found to indicate the average temperature of the deep-ocean water surrounding the Foraminifera as they build their shells. The ratio is measured in parts per million (how many atoms out of one million are oxygen-18).

Procedure

A scientist has conducted an experiment to test the relationship between the average deep-ocean temperature and the oxygen-18 ratio of Foraminifera shells. To do this, the amounts of oxygen-18 and oxygen-16 in Foraminifera shells and the temperature of the surrounding ocean water are measured. The results of this investigation are plotted on the following graph.



Analysis

1. Describe the overall trend in the data suggested by the "Relationship Between Temperature and Oxygen-18: Oxygen-16 Ratio" graph by completing this sentence:

   As the average deep-ocean temperature increases, the ratio of oxygen-18 to oxygen-16 _____.

2. Determine the slope of the best-fit line for this graph. Remember to include units.
3. Consider your answers to questions 1 and 2. Concisely explain how the answer to question 2 also includes the answer to question 1.

Part B: Oxygen Isotopes in Ocean Sediments

Problem

Can the oxygen-18 to oxygen-16 ratio data from Foraminifera fossils found in ancient sedimentary rock be used to determine the changes in average temperature during the Tertiary Period?

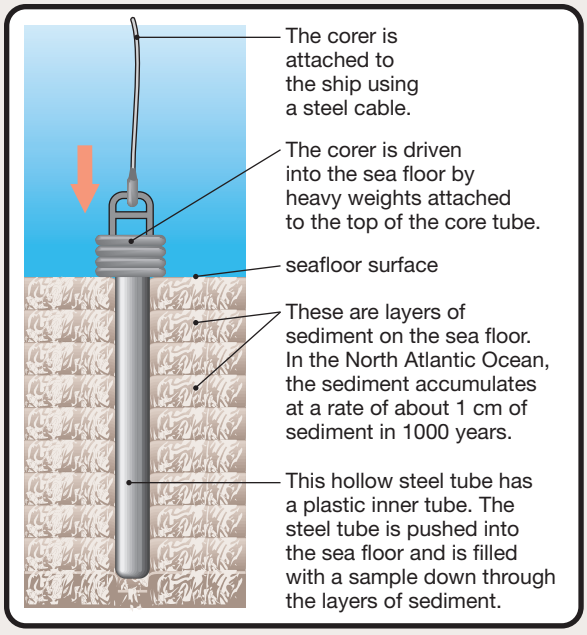

The corer is attached to the ship using a steel cable.
The corer is driven into the sea floor by heavy weights attached to the top of the core tube.
seafloor surface
These are layers of sediment on the sea floor. In the North Atlantic Ocean, the sediment accumulates at a rate of about 1 cm of sediment in 1000 years.
This hollow steel tube has a plastic inner tube. The steel tube is pushed into the sea floor and is filled with a sample down through the layers of sediment.

Figure C3.13: Heavy weights drive a hollow tube made of steel into the ocean floor. The core sample of sedimentary rock is then removed from the hollow tube for further study.

Procedure

As shown in the following table, an expedition travels to the North Atlantic Ocean and obtains a core sample of sedimentary rock from the ocean floor. The age and the ratio of oxygen-18 to oxygen-16 is then determined for each layer of sedimentary rock.

The following table data represents the first part of the data collection and analysis.

Time (10^6 a before present)	Oxygen-18: Oxygen-16 Ratio (ppm)	Average Deep-Ocean Temperature (°C)
50	1.0	
45	1.1	
40	1.9	
35	1.7	
30	2.2	
25	2.3	
20	2.4	
15	2.0	
10	3.3	
5	3.2	

Analysis

4. Create your own table. Use the graph from Part A to complete the table's blank column.
5. Plot a graph of this data with time on the horizontal axis and average deep-ocean temperature on the vertical axis. Remember to scale the horizontal axis so that 50 million years before the present is on the far left. Zero, representing the present, needs to be on the far right.

Conclusions

6. Describe the overall trend in average deep-ocean temperature during the Tertiary Period.
7. Does the graph show a constant decline in temperature or are there fluctuations?
8. Does the graph show all the fluctuations in average deep-ocean temperature during the Tertiary Period? Explain your answer.

3.1 Summary

The end of the Mesozoic Era was marked by the extinction of many of Alberta's life forms, including large dinosaurs. As the Tertiary Period—from 65 million years ago to 1.7 million years ago—of the Cenozoic Era began, Alberta was already a cooler, drier place than it had been during the age of dinosaurs. The Bearspaw Sea had drained to the southeast as a tectonic collision caused a relatively rapid period of mountain building. Small, rodent-like mammals flourished at the beginning of the Tertiary Period in an environment that resembled the modern-day southern part of Louisiana. Fossil evidence shows that the average global temperature fluctuated throughout the Tertiary Period but overall underwent a cooling trend. By the end of the Tertiary Period, many new forms of mammals were living in a much cooler Alberta. Due to the new dominance of grasses, large herds of grazing mammals roamed the landscape. Many people would be surprised to know that rhinoceroses, camels, giant pigs, and elephant-like creatures were part of Alberta's past.

3.1 Questions

Knowledge

1. What evidence of climate change can you identify near Okotoks, Alberta?
2. Describe how the Blackfoot Nation explanation of Big Rock's origins is both similar to and different from the scientific explanation.
3. Describe how water erosion and ice erosion are similar processes.
4. What event marked the beginning of the Cenozoic Era?
5. Why is Cypress Hills Interprovincial Park significant to the study of the Cenozoic Era?
6. What two periods make up the Cenozoic Era?
7. What percentage of the Cenozoic Era is made up of the Tertiary Period?
8. What caused the rapid period of mountain building that took place during the first 15 million years of the Tertiary Period?
9. Describe the appearance of the Rocky Mountains before glaciation.
10. Relate one possible reason for the overall cooling trend during the Tertiary Period.
11. After the extinction of the big dinosaurs, which two groups of animals moved in on their territory?
12. Did all dinosaurs become extinct? Explain.
13. Explain why the Tertiary Period could be described as the rise of the mammals.
14. Give two possible reasons why grasses became dominant plants in Alberta during the late Tertiary Period.

Applying Concepts

15. As the graphic in Figure C3.14 shows, there are many types of *Foraminifera*, which is a group of tiny marine organisms. *Foraminifera* have shells that contain calcium carbonate. Calcium carbonate is a main component of limestone. The interior plains of Alberta have mainly limestone-rich soils. What does the presence of limestone within Alberta's soil indicate about Alberta's environment during much of the province's past?

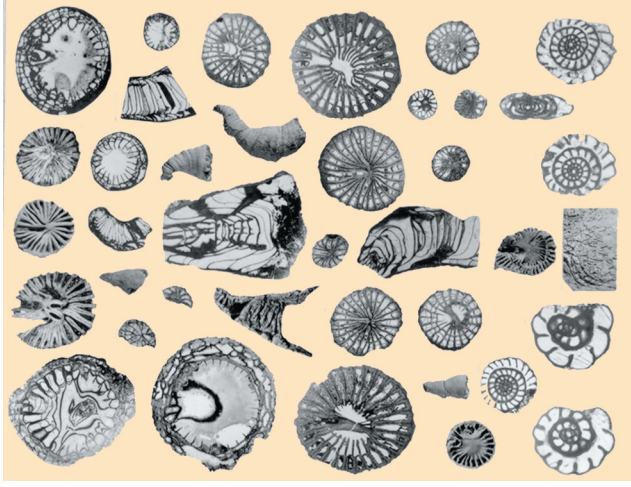


Figure C3.14: Foraminifera is a group of tiny marine organisms.